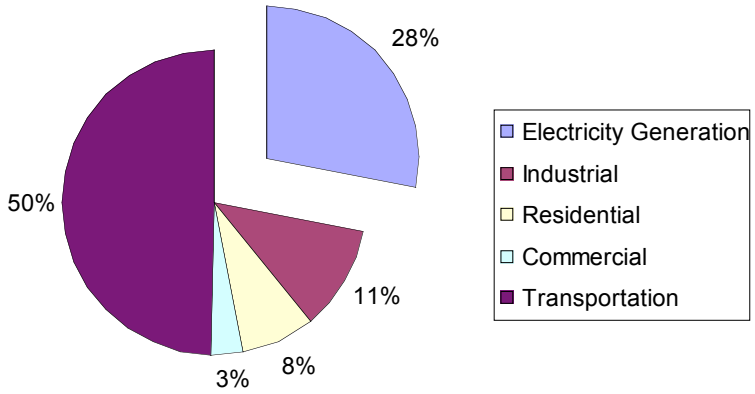
Panel Discussion on Climate Change Science: Impacts, Adaptation and Climate Change Mitigation Strategies

Kelly Birkinshaw (California Energy Commission)
Dan Cayan (Scripps Institute of Oceanography)
Lynn Price (Lawerence Berkeley National Lab)
and Michael Hanneman (U.C. Berkeley)

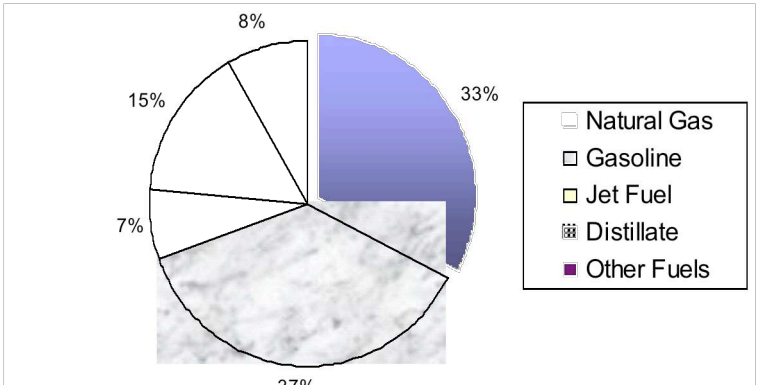
Energy is a major Contributor to the GHG Emissions Inventory

- If out-of-state power plants are counted in the State GHG inventory, the overall contribution is about 28%.
- Natural gas use accounts for 33% of the State GHG inventory

CO_2 Emissions from Electricity



CO_2 Emissions from Natural Gas



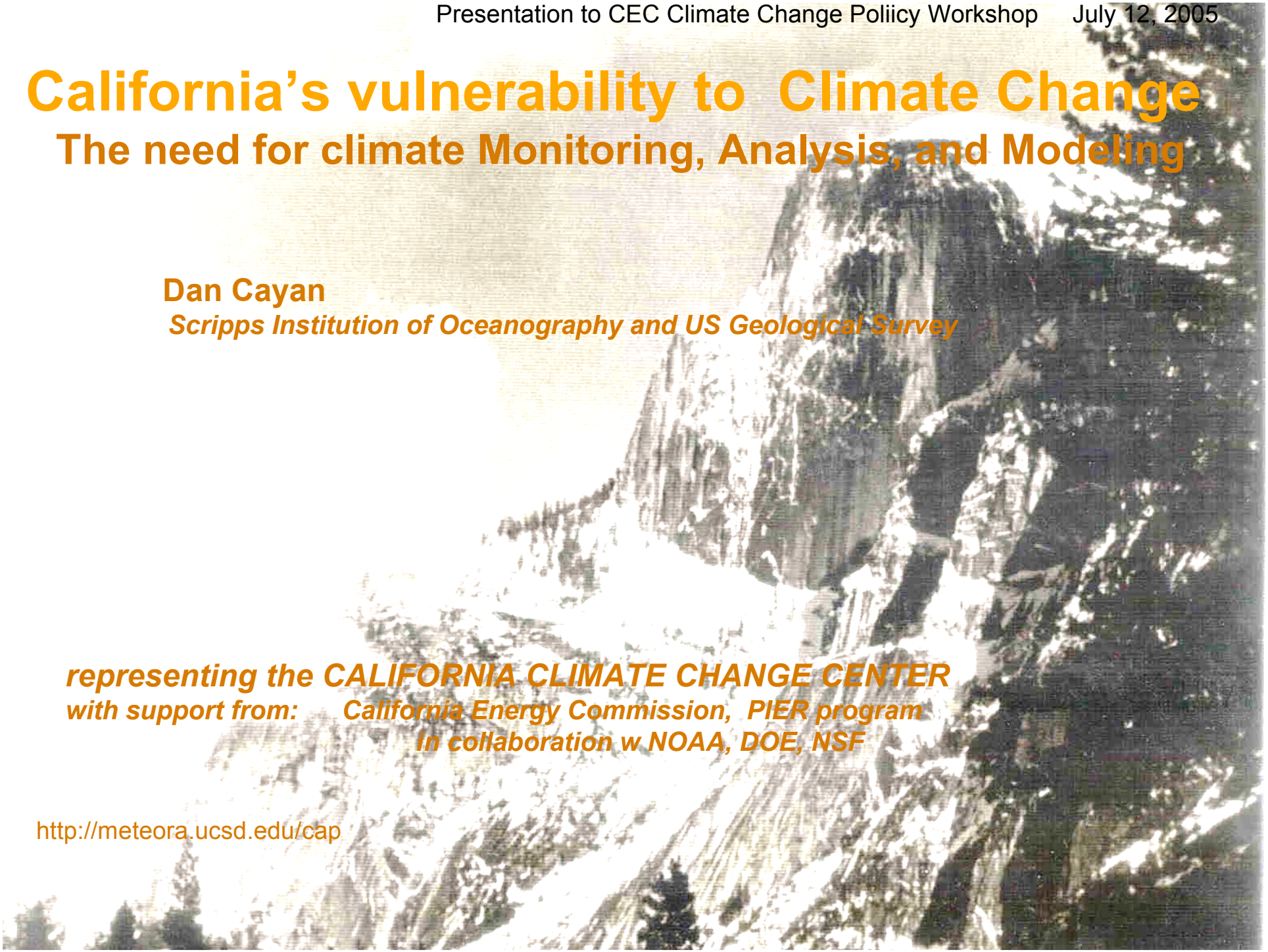
Major Policy Issues Foundational for the Project Portfolio

- What are plausible climate change scenarios for California?
- How would climate change (physical impacts) affect the States' environment and economy?
- What are the merits of the range of mitigation and adaptation strategies?
- How would climate change affect energy supply and demand?
- How would climate change policies affect the economy?

California's vulnerability to Climate Change

The need for climate Monitoring, Analysis, and Modeling

Dan Cayan
Scripps Institution of Oceanography and US Geological Survey

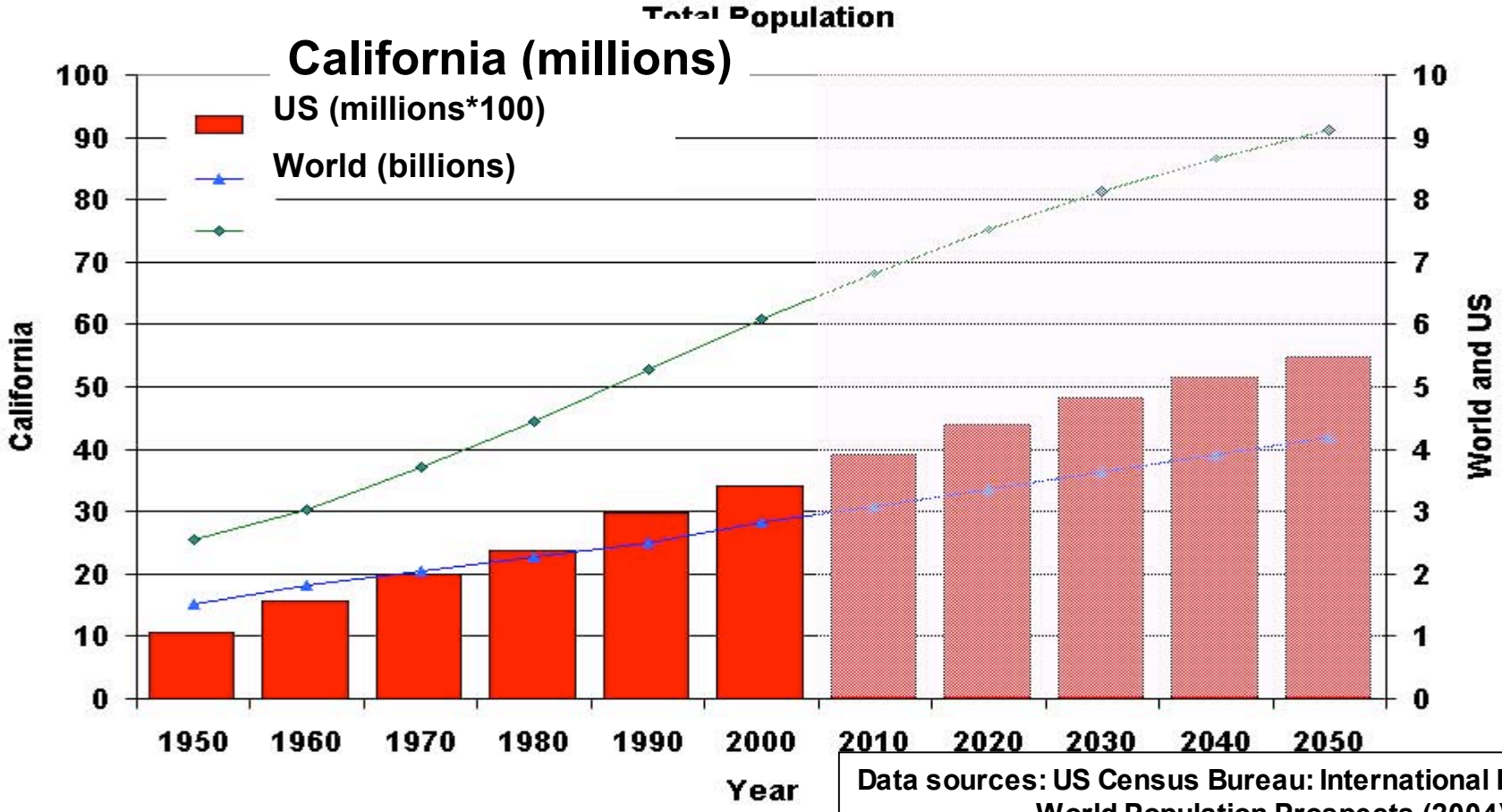


representing the CALIFORNIA CLIMATE CHANGE CENTER
with support from: California Energy Commission, PIER program
in collaboration w NOAA, DOE, NSF

http://meteora.ucsd.edu/cap

California's population increase closely mirror's global total

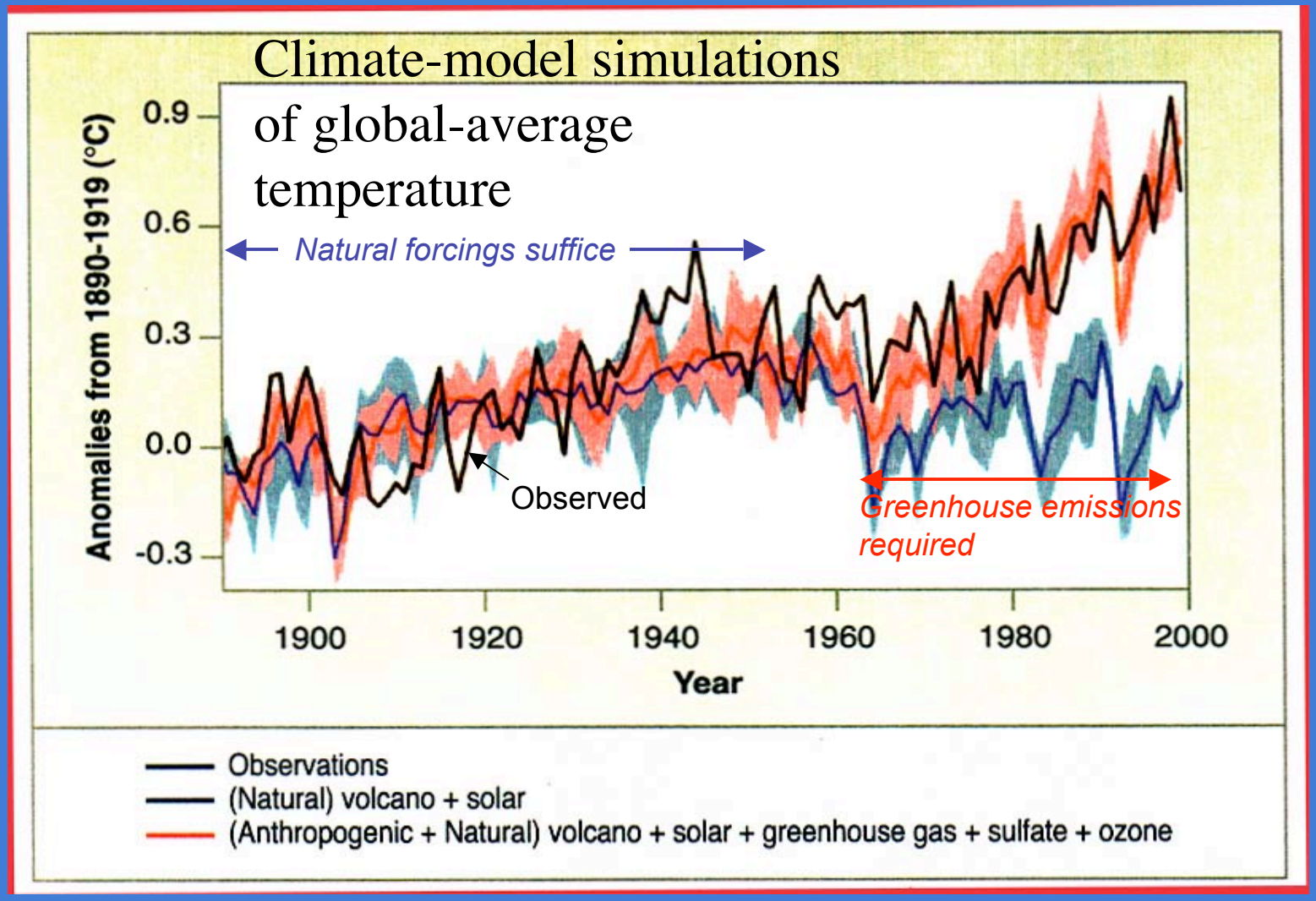
Increases in global and state population Are somewhat uncertain but will have profound impacts on California climate



Data sources: US Census Bureau: International Data Base
World Population Prospects (2004)
California Department of Finance (Oct 2004)

Model experiments indicate that

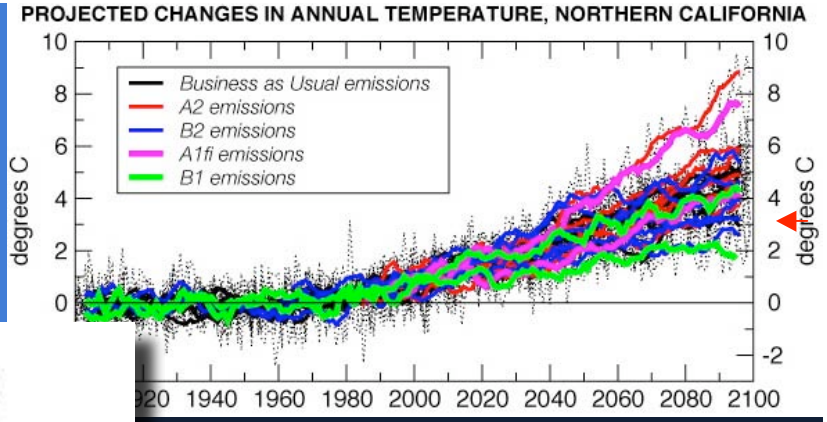
Recent climate warming appears to be *largely* due to increases in the global greenhouse effect.

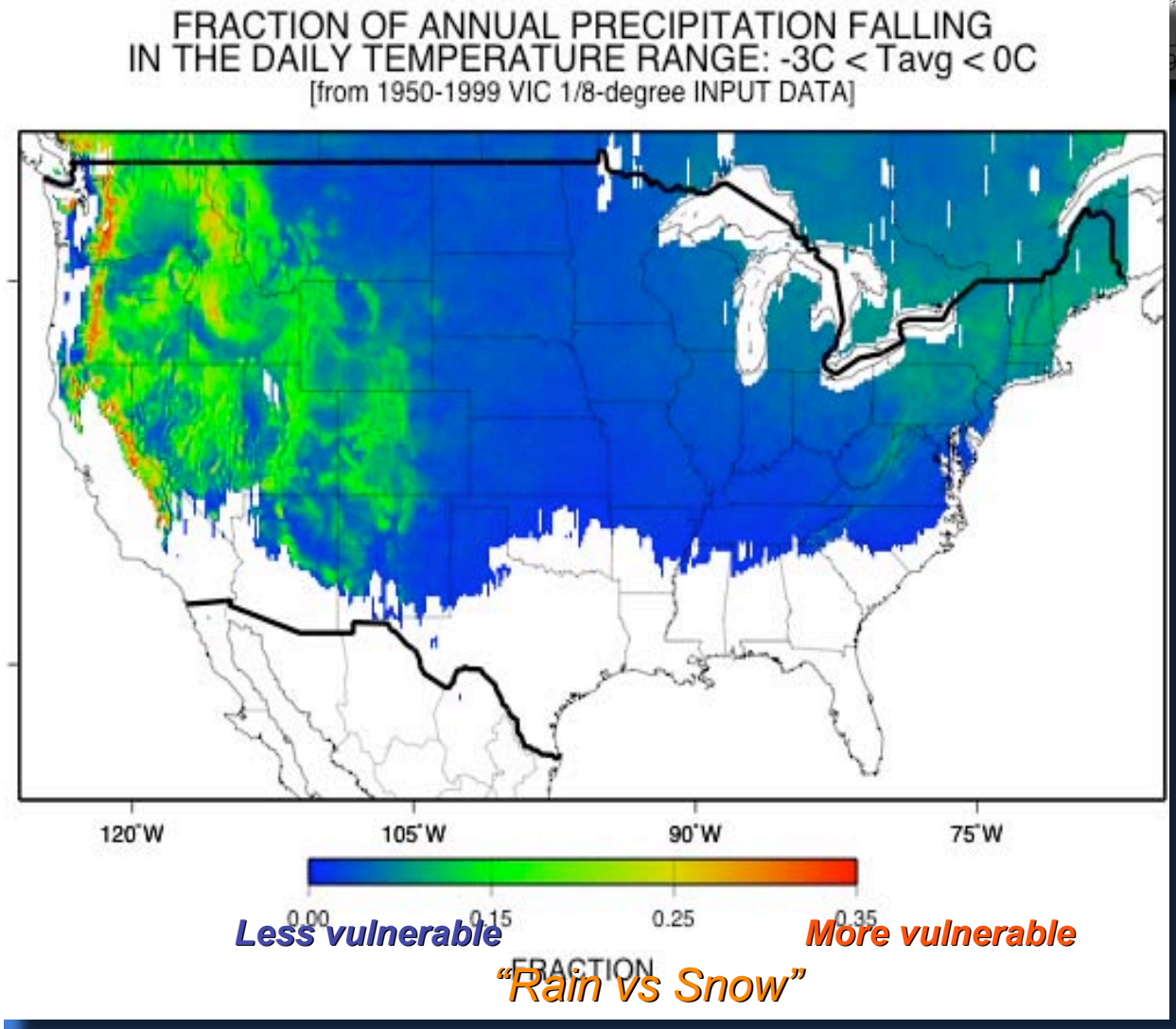


Meehl et al., 2004 J. Climate

Using the historical (1950-99) record:

What is the likely influence of a uniform +3ºC warming on **SNOW vs RAIN contributions?**





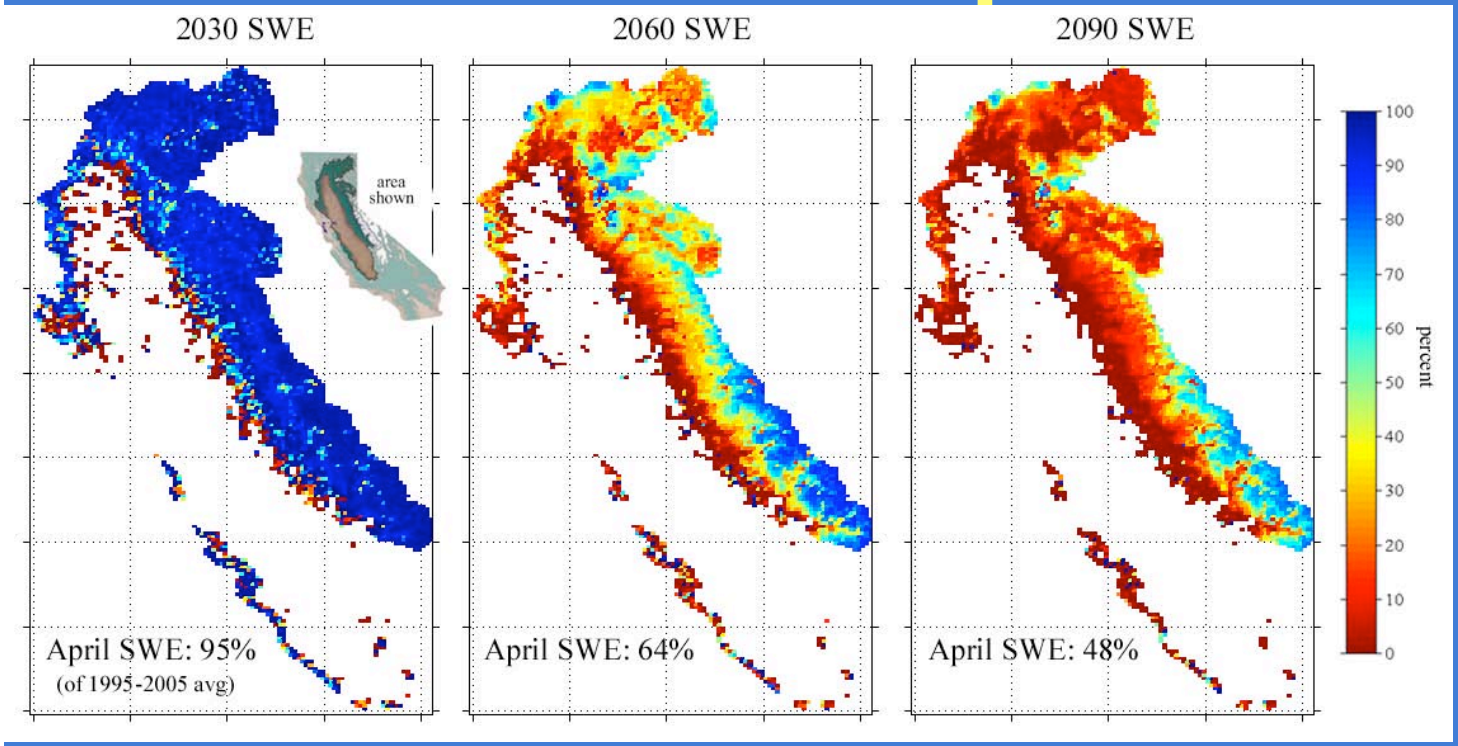
California and other parts of the West are extremely vulnerable

Computed from UW's VIC model daily INPUTS (Nijssen et al, 2001)

Mike Dettinger

USGS

We face significant losses of spring snowpack



- Less snow, more rain
- Particularly at lower elevations
- Earlier run-off
- More floods
- Less stored water

By the end of the century California could lose half of its late spring snow pack due to climate warming. This simulation by Noah Knowles is guided by temperature changes from PCM's Business-as-usual coupled climate simulation.
(a middle of the road emissions scenario)

better understanding of present day and future snow accumulation and melt processes is needed

***But, there are still considerable uncertainties*:**

models

emission scenarios

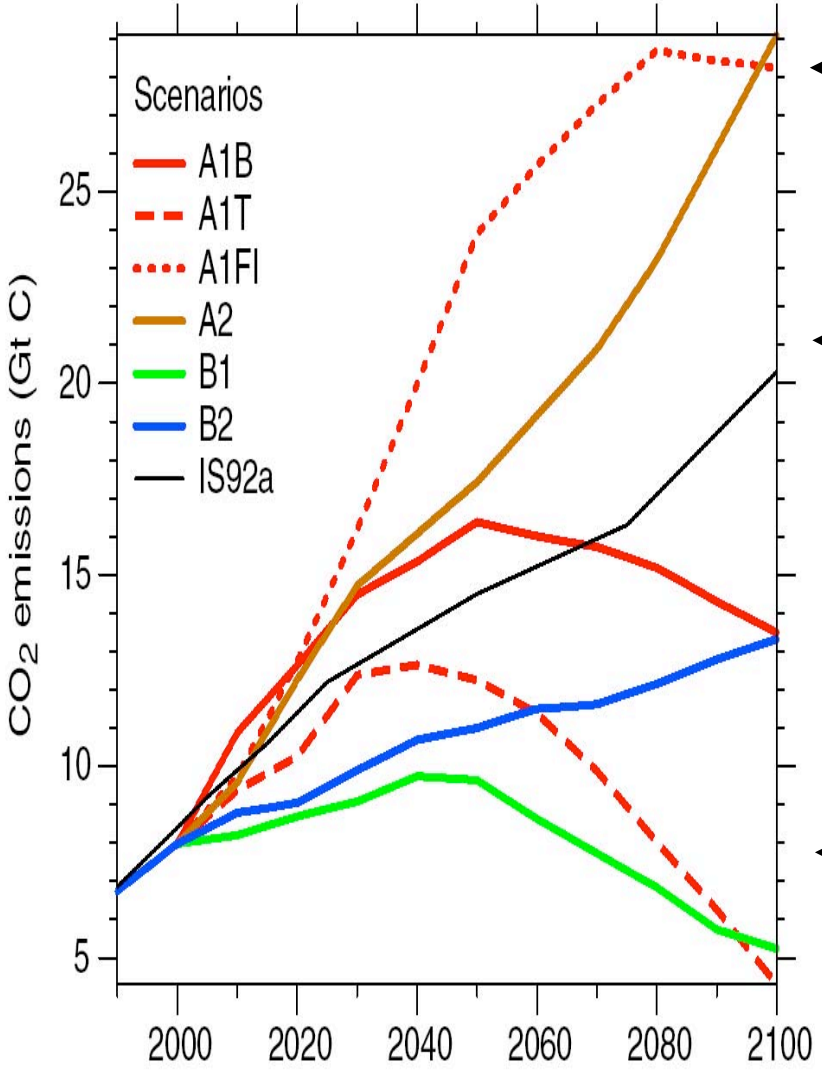
observations

fundamental physical understanding

while future emissions will continue, their levels could be more or could be less…, and climate would respond accordingly

Global CO2 Emissions Scenarios

Intergovernmental Panel on Climate Change (IPCC)



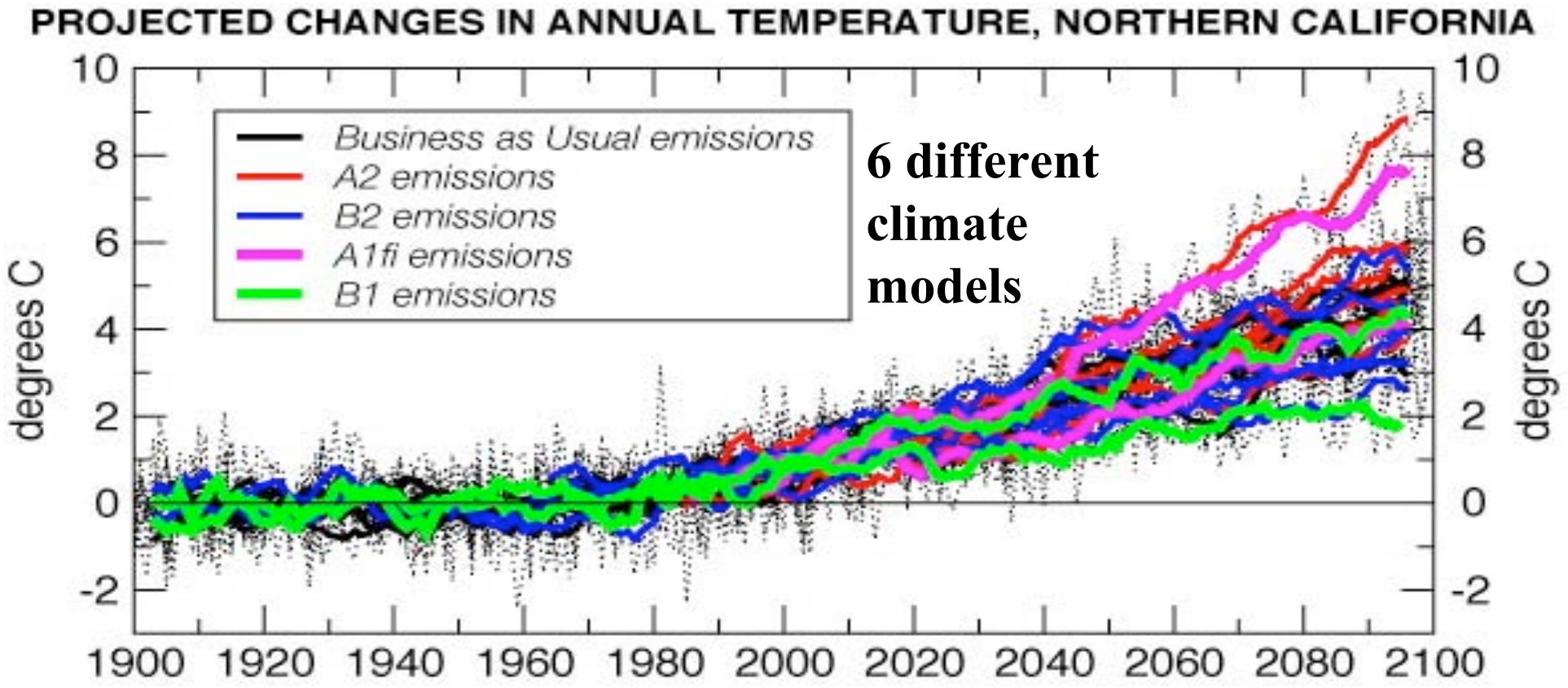
Higher (A1fi)

Previous (IS92a)

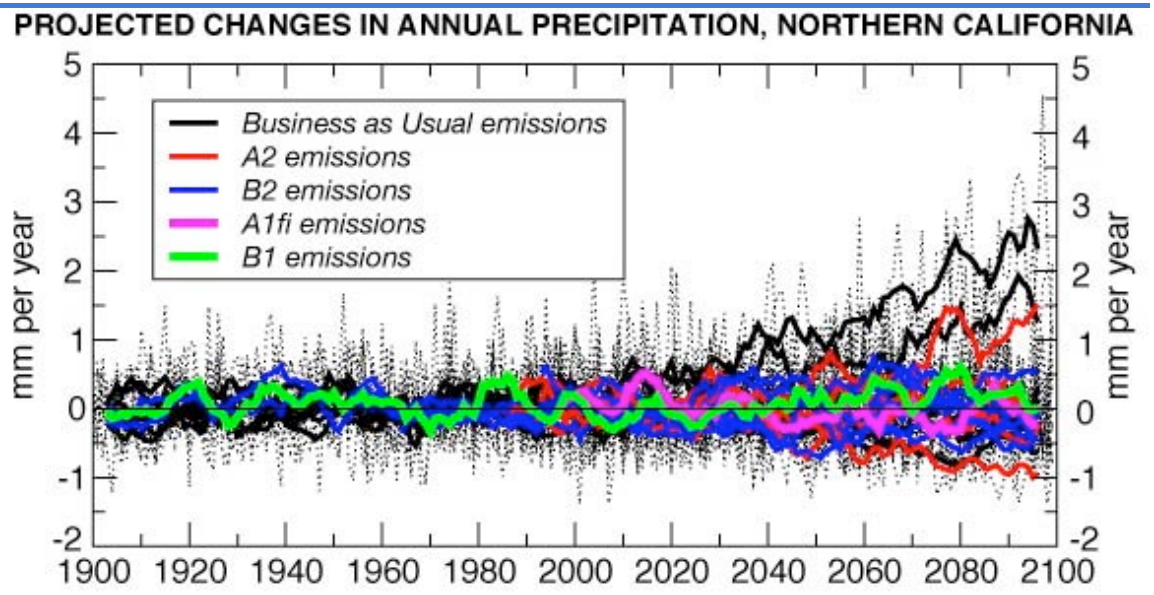
Lower (B1)

CO2 and other GHG Have long lifetimes In the atmosphere

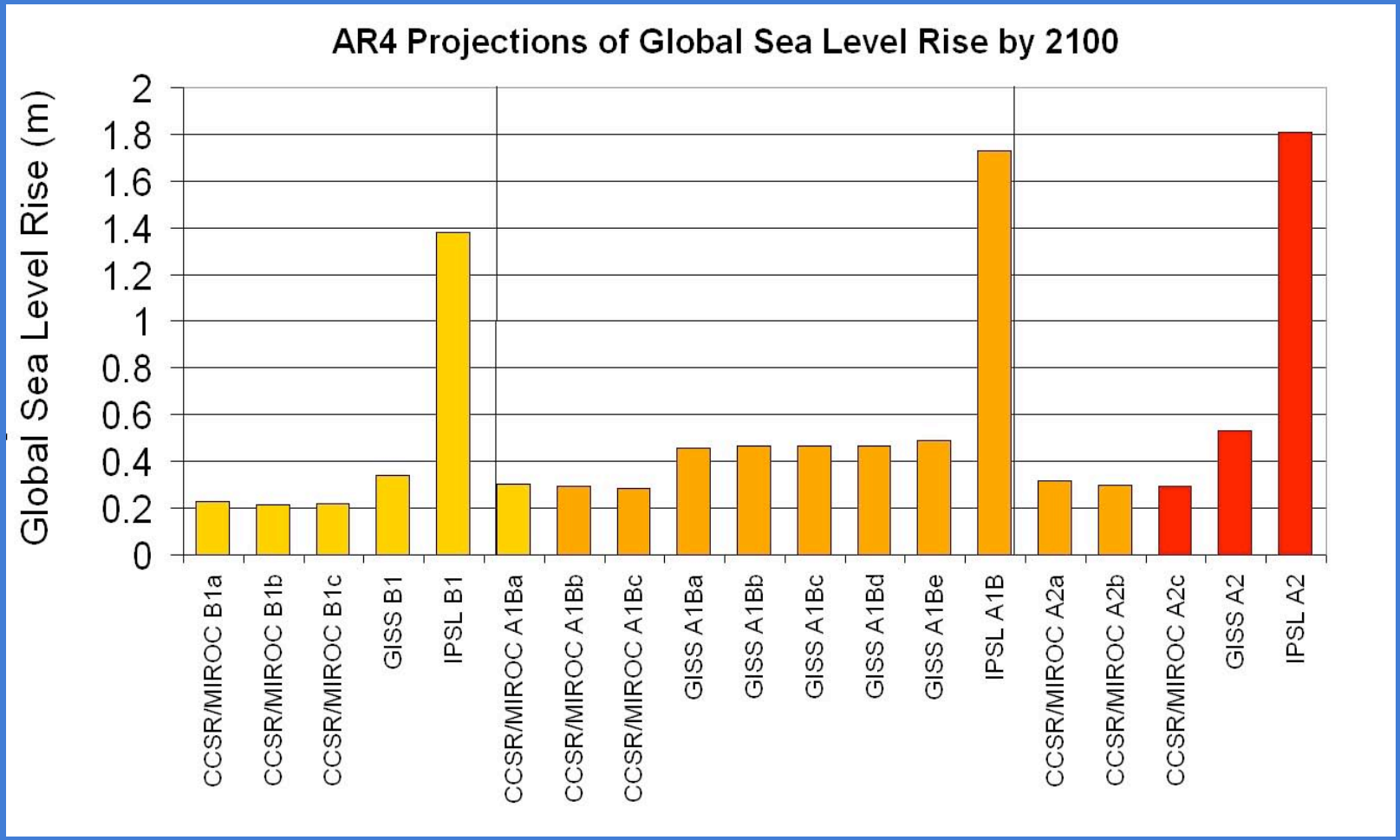
Lower emissions would approx double CO2 by 2100, but higher emissions would approx triple CO2 by 2100



Strong concensus for warming
But large uncertainty with precipitation



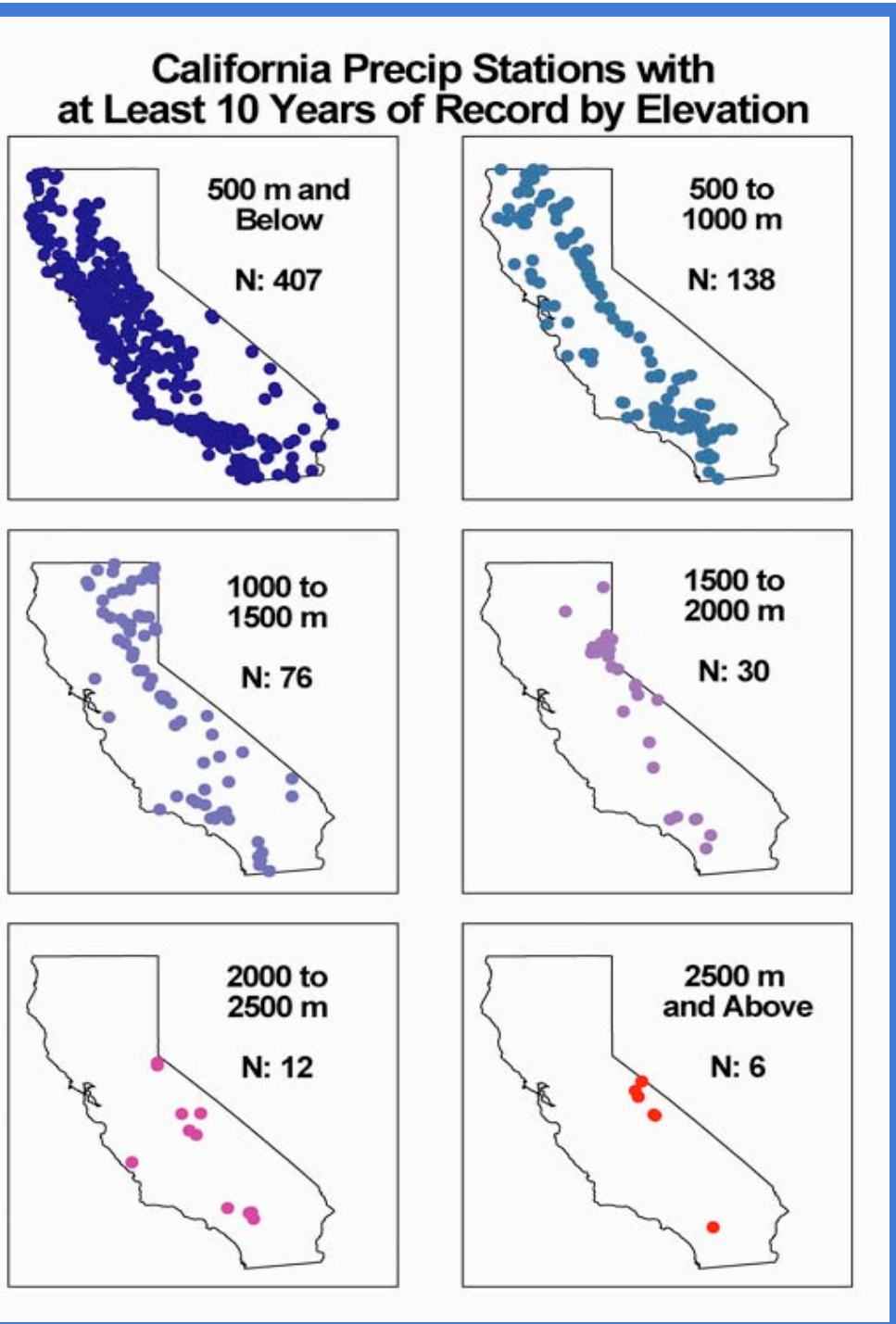
Accelerations in sea level rise are likely, but not well represented in global climate models



Courtesy of Katherine Hayhoe 2005

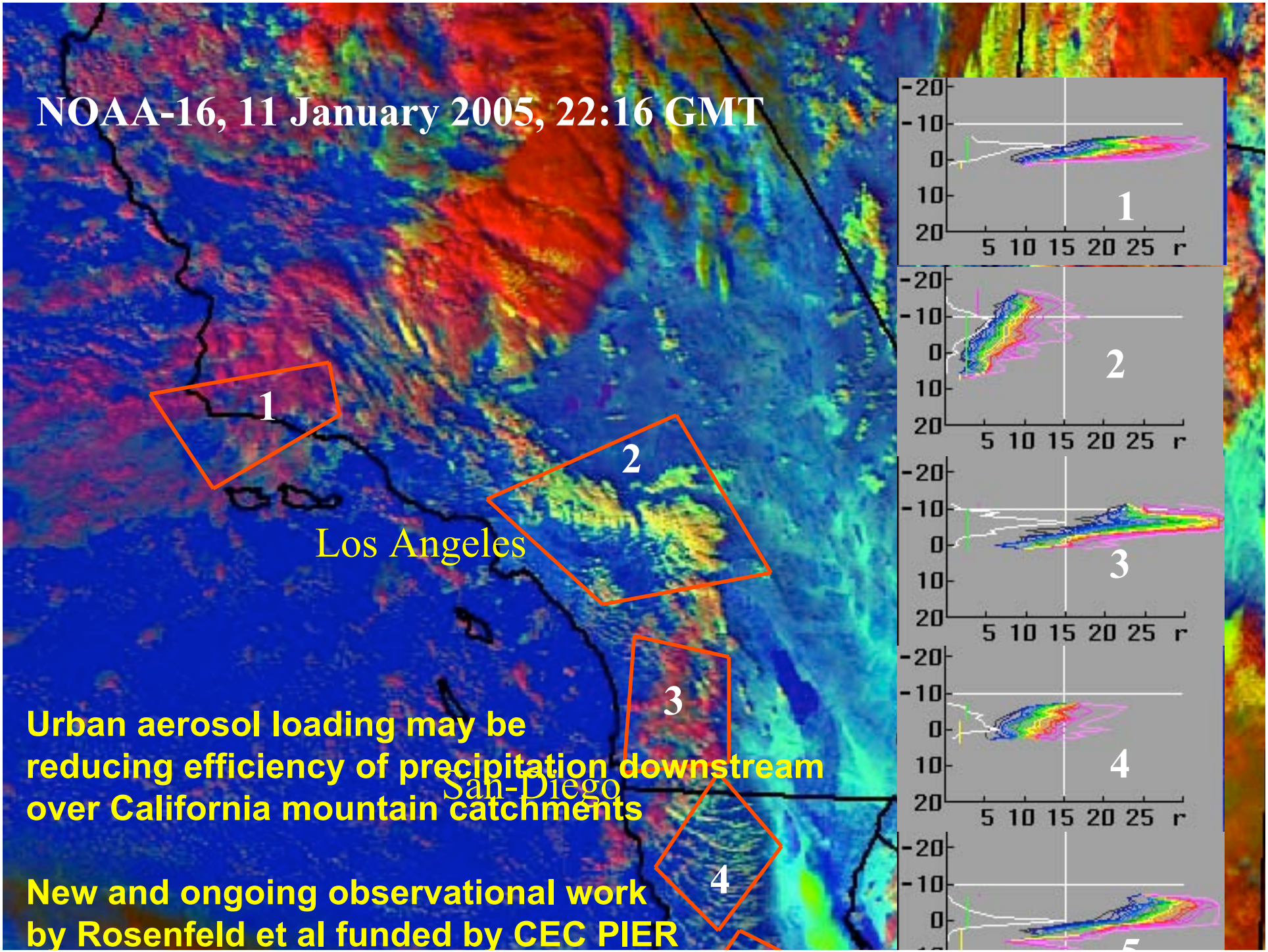
California needs more mid-high elevation climate stations!

Most of California's Precip gauges are sited in low elevation population centers. Yet, a lot of our concern is for climate changes in mid-high elevations.



The CEC CCCC,
Desert Research Inst.,
USGS, and the
Ntl Park Service
Is collaborating with
California DWR to
Install snow and weather
Stations in the
Sierra Nevada

Photo shows Frank Gehrke,
Chief of California Snow Surveys
Installing accoustic anemometer
At Dana Meadows, July 6, 2005


NOAA-16, 11 January 2005, 22:16 GMT
1
2
Los Angeles
3
San-Diego
4
Urban aerosol loading may be reducing efficiency of precipitation downstream over California mountain catchments
New and ongoing observational work by Rosenfeld et al funded by CEC PIER
-20
-10
0
10
20
5 10 15 20 25 r
1
2
3
4

GREENHOUSE GAS MITTIGATION STUDIES

Lynn Price
Deputy Group Leader of the International Energy Studies Group
Energy Analysis Department
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory

The Policy Problem

- Determining the optimal mix of greenhouse gas reduction strategies for California requires a thorough understanding of emissions sources and characteristics, and the costs of potential abatement measures

PIER-Sponsored Greenhouse Gas Mitigation Studies

- ***Development of Energy Balances for the State of California***
  Lawrence Berkeley National Laboratory
- ***Optimization of Product Life Cycles to Reduce Greenhouse Gas Emissions in California***
  Lawrence Berkeley National Laboratory
- ***Emission Reduction Opportunities for Non-CO2 Greenhouse Gases in California***
  ICF Consulting
- ***Carbon Supply From Changes In Management of Forest, Range, and Agricultural Lands of California***
  Winrock International
- ***Research Roadmap for Greenhouse Gas Inventory Methods***
  University of California - Berkeley, Lawrence Berkeley National Laboratory, California Energy Commission PIER

PIER-Sponsored Greenhouse Gas Mitigation Studies

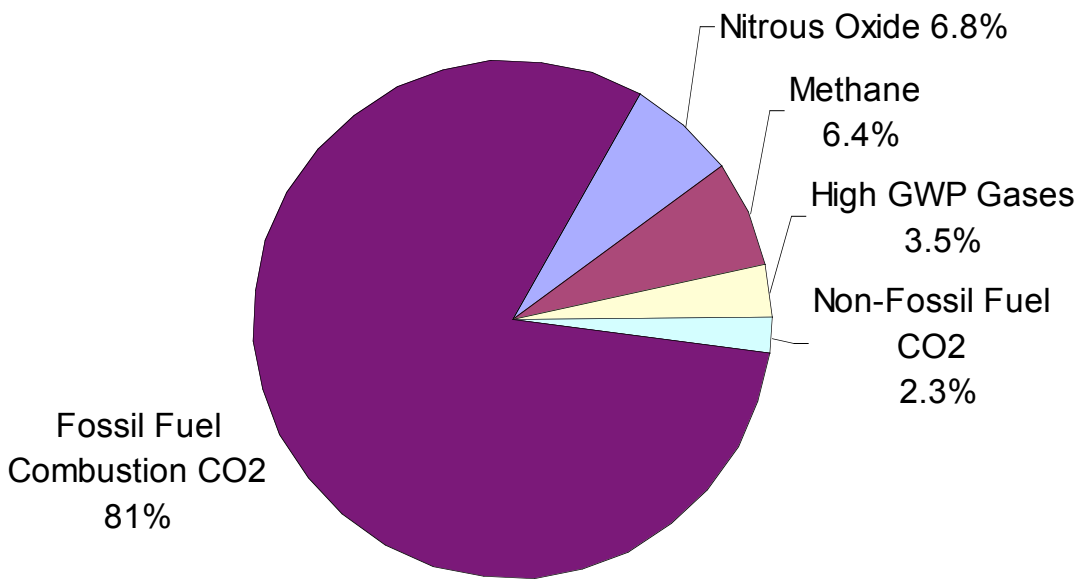
- ***WESTCARB: Developing Sequestration Options for the West Coast: Phases I and II***
  Lawrence Berkeley National Laboratory
- ***Assessment of Carbon Sequestration Potential in California Agricultural Soils***
  University of California – Davis
- ***Developing and Applying Process-based Models for Estimating GHG and Air Emissions from California Dairies***
  Applied Geosolutions, LLC, California State University at Fresno, University of California – Davis, University of California – Riverside
- ***Development of Long-Term Energy Efficiency Supply Curves***
  Quantum, Lawrence Berkeley National Laboratory, University of California – Berkeley

Common Characteristics of PIER Climate Change Mitigation Research Activities

- Goals are to:
  - Improve understanding of California GHG emissions trends
  - Understand California-specific mitigation options and costs
- Strong involvement of other state and federal agencies in all phases of many of the projects, including co-funding and in-kind donations (e.g., California Department of Forestry, California Department of Food and Agriculture, U.S. Department of Energy, U.S. Forest Service)
- PIER reports have been widely used:
  - Development of California GHG Inventory (CEC)
  - Development of forestry reporting protocol (California Climate Action Registry)
  - Analysis of policy options (Center for Clean Air Policy, Tellus Report)

Understanding California's Greenhouse Gas Emissions

California Greenhouse Gas Emissions, 2002



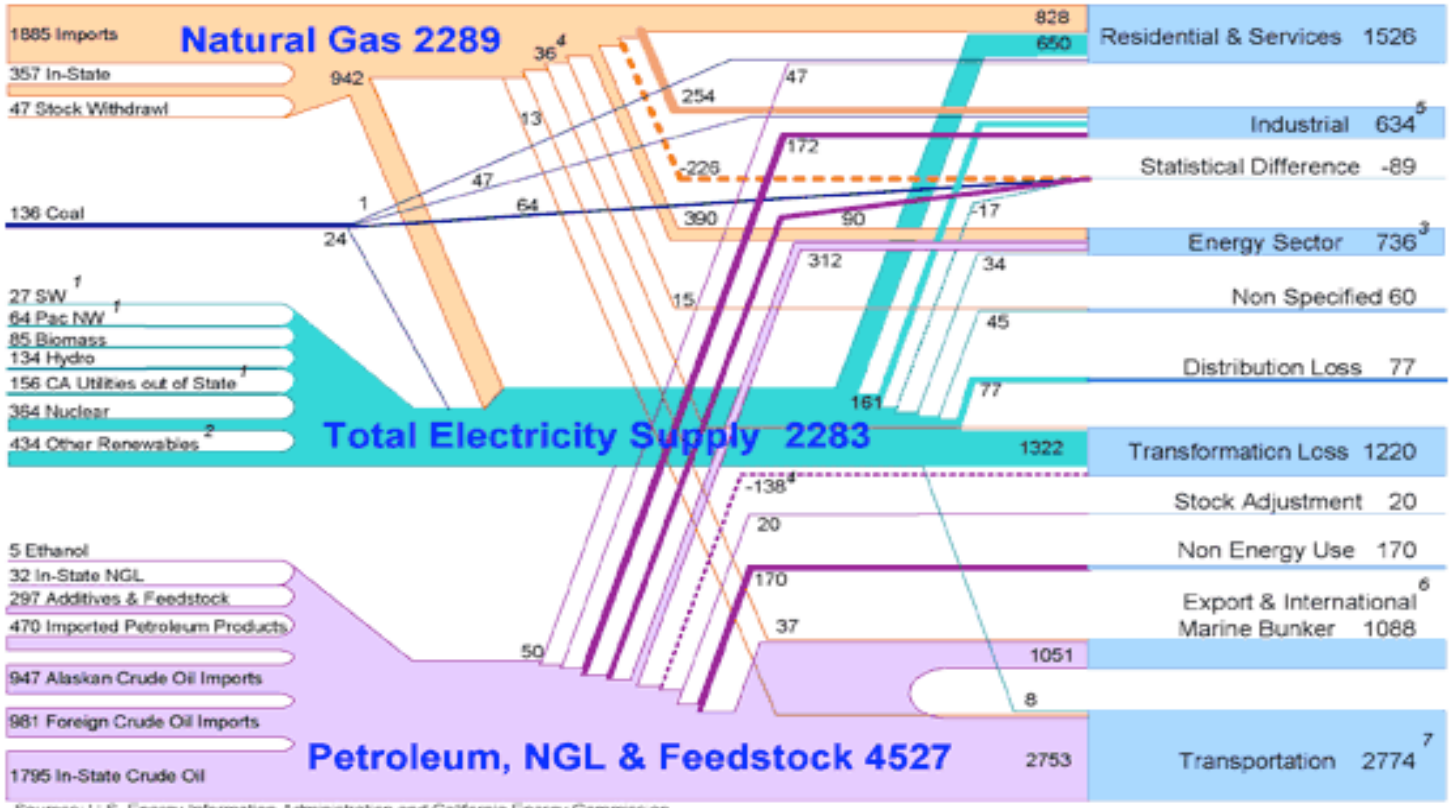
Source: California Energy Commission

Understanding California's Greenhouse Gas Emissions

- Development of annual Energy Balances for California provides more detailed understanding of fossil-fuel combustion CO_2 emissions
  - By fuel type
    - » Natural gas
    - » Petroleum – including liquefied petroleum gas, motor gasoline, kerosene, distillate oil, residual oil, petroleum coke, lubricants
    - » Coal
  - By economic sector
    - » Transportation
    - » Industry
    - » Residential and commercial buildings
    - » Agriculture
    - » Electricity production

Understanding California's Greenhouse Gas Emissions

California Energy Flows, 2000 (trillion Btu)



Sources: U.S. Energy Information Administration and California Energy Commission.

1. Electricity flowing into the California Control Areas: CAISO, LADWP, and IID.
2. Other Renewables includes geothermal, wind, solar, landfill gas and municipal solid waste.
3. Energy used by oil refineries and for oil and gas extraction.
4. 36 TBtu of natural gas used as feedstock in refineries, so total unexplained transformation gain is 102 TBtu.
5. Industrial includes agriculture and mining.
6. Following the International Energy Agency energy balance format, deliveries of fuels to ocean-going vessels with foreign destinations are reported separately from the transportation sector.
7. 220 TBtu of fuel appearing in the transportation sector was used for international civil aviation.

..... Dotted lines indicate negative values

Research and Data Needs: CO_2 Emissions

- **Improve understanding of California GHG emissions and trends**
  - Improve accounting for liquid fuels
    - » Increase detail and reduce uncertainty regarding bunker fuels
    - » Improve accounting of minor fuels
    - » Develop California-specific estimates of petroleum feedstocks
  - Improve estimation of CO_2 emissions from electricity, especially for imports and exports
  - Collect fuel consumption data for all fuels in a systematic and statistically valid manner
  - Collect and analyze activity data for decomposition studies (population, GSP, floor space, vehicle types, etc.)
- **Understand California-specific mitigation options and costs**
  - Long-term energy efficiency supply curves
  - Long-term alternative energy pathways for California

Research and Data Needs: Non-CO_2 Emissions

- **Improve understanding of California GHG emissions and trends**
  - Need to reduce current high levels of uncertainty associated with existing methods
  - Improve data and inventory methods
    - » N_2O from agricultural soils
    - » Landfill methane
    - » Manure management systems
    - » Landfill waste characteristics, waste generation and landfilling rates
    - » High GWP gases
    - » Improve process-based model for estimating emissions from California dairies
  - Explore use of inverse methods for tracking emissions and "validating" bottom-up methods
- **Understand California-specific mitigation options and costs**
  - Detailed engineering analyses to better understand statewide reduction opportunities for key sectors (landfills, manure management, semiconductors, refrigeration and AC)
  - Evaluate other non-CO_2 mitigation opportunities

Research and Data Needs: Carbon Sequestration

- **Improve understanding of California GHG emissions and trends**
  - Collect data on agricultural management practices to account for regional and cropping system differences
  - Improve modeling of carbon-nitrogen dynamics, N_2O, and CH_4 over a range of California agro-ecosystems
  - Develop or demonstrate new methods that could be used to cost-effectively measure the carbon content in agricultural soils
- **Understand California-specific mitigation options and costs**
  - Develop and validate methods for assessing carbon emissions avoided by mitigation of catastrophic forest fires
  - Demonstrate the sequestration capacity of candidate geologic formations in California
  - Pilot studies to focus on CA-specific options:
    - » CO_2 injection into a gas reservoir
    - » CO_2 storage from afforestation and forest fire mitigation by fuel removal

ECONOMICS OF CLIMATE CHANGE

Michael Hanneman

California Climate Change Center at
UC Berkeley

The Policy Questions

- How will regional climate change affect the California economy?
  - What are the key economic vulnerabilities?
  - What adaptations will be necessary, and at what cost?
- How can California undertake significant greenhouse gas (GHG) mitigation while continuing to achieve robust economic growth?

Overall Approach

- Studies of individual sectors (impact + adaptation)
  - Water
  - Agriculture
  - Forestry
  - Energy
  - Coastal resources
- Overall statewide impacts
  - Technology adoption policies
  - Policies to reduce emissions (cap & trade, etc)
  - Overall statewide economic model

Climate & Water in California

- Water district is key unit of observation
- Focus on reliability & economic value of changes in reliability
- Combines hydrology and economics
- Measure existing (baseline) reliability
- Model change in deliveries & reliability
- Assess loss of income & consumers surplus due to change.

Climate & Water in California

- To implement this, developing a hydrologic-economic model of water in California, based on a simulation approach.
- The results will be compared with those of CALVIN, which uses a non-probabilistic, global optimization approach, and a broader level of spatial aggregation.
- Key issues relate to reduction in Sierra snow pack, in summer streamflow, hence in effective water supply. Possibly more flooding and increased drought.

Some other impacts on water supply

- With higher sea level, there is greater potential for sea water intrusion into Delta.
- Also, some potential for sea water intrusion into coastal aquifers.
- Increased evaporation from surface storage.
- Greater chance of fires in watershed areas, leading to silt & sediment.
- More groundwater overdraft due to more frequent dry spells.
- Climate changes also affects Colorado River.

California Agriculture

- Higher temperatures and solar radiation raise crop water need (ET).
- Higher temperatures are likely to reduce crop yield and/or quality (e.g., grapes).
- Unclear effect of CO2 fertilization
- Effect of climate change on agricultural pest populations.
- Higher water and energy costs for ag.

California Forestry

- Effect of climate change on timber yield and commercial timber harvesting in California.
- Effect of higher temperatures on forest fires in commercial forests and urban wildland areas.

California Energy

- Reduced hydropower production.
- Increased energy demand for summer cooling.
- Greater reliance on groundwater pumping increases energy demand.
- Emission reduction strategies encourage reduced use of fossil fuel in electricity generation.

Coastal Resources

- Coastal flooding and property losses
- Beach erosion, cost of increased beach replenishment and/or reduced beach recreation
- Possible impact on wetland resources

New California Economic Model

- New dynamic computable general equilibrium (CGE), the "BEAR" model.
- Detailed economic and emissions
  - Currently a 20-sector aggregation - underlying data will support 104 economic sectors
  - 10 household groups (by tax bracket)
  - Detailed governmental fiscal accounts
  - 14 categories of emissions
  - Energy efficiency growth and technical change

Policy Research

- The microeconomics of energy-efficiency adoption
- The role of government in stimulating innovation in the development of environmentally-friendly technologies
- Alternative ways to design a GHG emissions trading program for California

Research and Data Needs

- 1) Governor's study will entail a first, partially qualitative integration of climate science, impact analysis, and economics
  - Important to follow this up with a more extensive and quantitative analysis
- 2) Further development of BEAR:
  - Disaggregation of sectors
  - Endogenization of technical change
  - More complete representation of technology adoption process
- 3) Much more disaggregated data on household energy use is required for rigorous climate impact analysis